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Sea slugs – divers’ favorites, taxonomists’ problems

Siput laut – disukai para penyelam, masalah bagi para taksonom

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Abstract: Sea slugs, or opisthobranch molluscs, are small, colorful, slow-moving, non-aggressive marine animals. This makes them highly photogenic and therefore favorites among divers. The highest diversity is found in tropical waters of the Indo-West Pacific region. Many illustrated guidebooks have been published, but a large proportion of species remain unidentified and possibly new to science. Lack of funding as well as expertise is characteristic for taxonomic research. Most taxonomists work in western countries whereas most biodiversity occurs in developing countries. Cladistic analysis and molecular studies have caused fundamental changes in opisthobranch classification as well as “instability” of scientific names. Collaboration between local and foreign scientists, amateurs and professionals, divers and academics can help discovering new species, but the success may be hampered by lack of funding as well as rigid regulations on collecting and exporting specimens for taxonomic research. Solutions to overcome these obstacles are presented.

Keywords: mollusca; opisthobranchia; biodiversity; citizen science; taxonomic impediment

Abstrak: Siput laut, atau moluska golongan opisthobranchia, adalah hewan laut berukuran kecil, berwarna, bergerak lambat, dan tidak bersifat agresif. Alasan inilah yang membuat hewan ini sangat fotogenik dan menjadi favorit bagi para penyelam. Keanekaragaman tertinggi hewan ini ditemukan di perairan tropis Indo-Pasifik bagian Barat. Banyak buku petunjuk tentang hewan ini telah diterbitkan, tetapi sebagian besar spesimen belum teridentifikasi dan bisa menjadi hal baru bagi ilmu pengetahuan. Kekurangan dana dan keahlian merupakan ciri khas dari penelitian taksonomi. Umumnya para taksonom bekerja di negara-negara Barat sedangkan keanekaragaman tertinggi hewan ini berada di negara-negara berkembang. Analisis cladistik dan kajian molekuler menyebabkan perubahan mendasar dalam klasifikasi opisthobranchia, demikian juga sering berubahnya nama ilmiah hewan ini. Kerjasama antara ilmuwan lokal dan asing, amatir dan profesional, penyelam dan akademisi dapat membantu dalam menemukan jenis-jenis baru, tetapi keberhasilannya dapat dihambat oleh kurangnya biaya dan peraturan yang kaku dalam mengumpulkan dan mengirim spesimen untuk penelitian taksonomi. Solusi dalam menyelesaikan masalah tersebut disampaikan dalam tulisan ini.

Kata-kata kunci: moluska; opisthobranchia; biodiversitas; halangan taksonomi

INTRODUCTION

The small, often brightly colored sea slugs living in shallow waters of most tropical seas have been eye-catchers for divers and underwater photographers over the years. The most colorful species are found in coral reef habitats, which are also the preferred diving localities, but sea slugs occur in other habitats as well. Sea slugs are often called nudibranchs, but this is only part of the group scientifically known as opisthobranch molluscs (Wägele and Klussmann-Kolb, 2005). Besides the nudibranchs (Nudibranchia) (Wägele and Willan, 2000), sea slugs comprise the bubble-shells or head-shield slugs (Cephalaspidea) (Mikkelsen, 1996; Malaquias *et al.*, 2009), sea hares (Anaspidea) (Klussmann-Kolb, 2004), side-gilled slugs (Notaspidea) (Willan, 1987), sap-sucking slugs

(Sacoglossa) (Jensen, 1996) and the holoplanktonic sea butterflies (Thecosomata) and sea angels (Gymnosomata) (Klussmann-Kolb and Dinapoli, 2006). The total number of species is unknown because new species are still being described, and poorly known species turn out to be synonyms of other species. Recent estimates are given as 5000-6000 species worldwide (Wägele and Klussmann-Kolb, 2005; Schrödl *et al.*, 2011).

Because of their often spectacular coloration and also because they are slow-moving, small and non-aggressive, they are highly photogenic and therefore favorites among underwater photographers. This is reflected in the number of popular picture books published from different countries and in different languages (e.g. Gosliner, 1987; Wells and Bryce, 1993; Debelius, 1996; Ono,

1999; Schrödl, 2003; Behrens and Hermosillo, 2005; Camacho-Garcia *et al.*, 2005; Valdés *et al.*, 2006; Gosliner *et al.*, 2008; Yonow, 2008; Chavanich *et al.*, 2010). Few of these books are exhaustive for the region covered, though some have pictures of more than 500 species. Furthermore, although several of the books have been written by professional taxonomists, many species have only been identified to genus or family level, and many of these are assumed to be unnamed and un-described. The same is seen in the various internet sites for sharing pictures of sea slugs.

The highest species diversity occurs in the tropical Indo-West Pacific, and particular diversity hotspots have been identified in the Philippines, Papua New Guinea and Guam (Gosliner, 2000; Carlson and Hoff, 2003; Jensen, 2007). It has been estimated that 15–40% of the species in the Indo-Pacific region are still unnamed and un-described (Gosliner and Draheim, 1996). This explains part of the problem with identifying sea slugs from pictures. More important, however, is the high variability of color pattern and body form. Hence preserved specimens for anatomical and/or molecular studies are needed. Even then taxonomists do not always agree on the delimitation of a given species, its synonyms or its generic or family affiliations. Taxonomy is a dynamic discipline. Adding new information may result in name changes, and in recent years the opisthobranch molluscs have undergone fundamental changes in phylogenetic relationships with associated changes in names and classification (Schrödl *et al.*, 2011).

The increasing popular interest in sea slugs is in contrast to the decreasing financial support for taxonomic research and the lack of taxonomic expertise for most marine invertebrates (Godfrey, 2002; Wheeler *et al.*, 2004; Boero, 2010; Wägele *et al.*, 2011). Furthermore, most taxonomists, including the few specializing in sea slugs, are located in Europe, North America and Australia, i.e. developed countries in temperate regions, whereas most biodiversity is found in the tropical Indo-West Pacific region, i.e. primarily developing countries (Gaston and May, 1992; Bouchet, 2006). Amateur taxonomists have always played an important role in discovering and describing new species (Pearson *et al.*, 2011). In recent years scientists have developed projects including so-called “citizen science” and/or parataxonomy (Basset *et al.*, 2000; Cohn, 2008). The present paper will present the opportunities and challenges of collaborations between professional and amateur sea slug

enthusiasts and between local students and scientists in Southeast Asia and foreign expert taxonomists. Based on experience some set-ups for a fruitful collaboration between local divers, professional taxonomists and national biodiversity managers will be presented.

Linnean shortfall

The fact that a high proportion of species remain un-discovered and un-described has been termed the Linnean shortfall. Many new species of opisthobranchs are described every year, most of them based on preserved specimens accumulated by taxonomists over many years. Gosliner and Fahey (2011) described 20 new species of the arminid genus *Dermatobranchus*, and the included type material had been collected between 1980 and 2008. This is not an exceptional case; in a monograph of the family Phyllidiidae 21 new species in four genera were described from type material collected between 1967 and 1992, in fact one paratype was a museum specimen from 1870 (Brunckhorst, 1993), and in a series of 10 papers reviewing Indo-Pacific Chromodorididae a total of 68 new species were described from material collected between 1970 and 1993, and again one paratype was a museum specimen from 1925 (Rudman, 1982, 1983, 1985, 1986a,b,c, 1987, 1988, 1990, 1995). This means that most taxonomists have a back-log of species that have been discovered, but not yet named and described. During most field collecting trips only one or a few specimens of each species are found, and unless many persons can be engaged in the effort, it may take several years to obtain enough material for describing a new species. Collaborating with local divers, scientists and students may greatly increase the likelihood of finding more specimens. International workshops where taxonomists from developed countries collaborate with scientists and students from developing countries have proved very successful in this respect, e.g. the workshops organized in Hong Kong by Brian Morton during the 1980s and 1990s (results summarized in Morton, 2003).

Stability of names

Scientific names are supposed to be unique descriptors of species, and when new species are described the taxonomist should consult existing descriptions of related species and ideally compare with existing type specimens to avoid creating “junior synonyms”. The problems in this connection concern (1) accessibility of old descriptions, which may be in rare publications and in languages not understood by most taxonomists, e.g. Danish,

Dutch, Russian or Japanese; (2) inadequate old descriptions with no or poor illustrations; (3) unavailable, lost or poor quality of type material (Godfrey, 2002; Bouchet and Strong, 2010). Organizations such as the Biodiversity Heritage Library (<http://www.biodiversitylibrary.org/>) are attempting to make old taxonomic publications available on the internet. Books and journal volumes are scanned and hence the quality of the electronic versions is variable, and language may still be a problem. Other projects build databases of taxon names and/or museum specimens, especially type specimens, e.g. World Register of Marine Species (Appeltans *et al.*, 2012) and Global Biodiversity Information Facility (Edwards *et al.*, 2000).

Inadequate species descriptions are not only something of the past. Present-day taxonomists will generally avoid describing new species if only one specimen is available, but sometimes such descriptions do occur, e.g. 5 of the 20 new species of *Dermatobranchus* were described from one specimen (Gosliner and Fahey, 2011). Other taxonomists, mostly those in favor of the PhyloCode, will include partial descriptions of species without formally assigning a binomial (Linnean) name. Thus Dayrat (2010) in a 400 page monograph of the family Discodorididae describes seven species (A-G), two of them assigned to different genera and the remaining five to a “metaphyletic genus level group”, a concept elaborated in a prior paper (Dayrat and Gosliner, 2005). This concept is difficult to comprehend for an experienced taxonomist, and probably leaves other users of taxonomy flabbergasted.

Name changes happen when species are synonymized or split, often in connection with revisions and/or when phylogenetic analysis shows that a genus is not monophyletic. Unfortunately different specialists sometimes reach different conclusions resulting in unstable names rather than the opposite. The nudibranch family Chromodorididae, probably the most species-rich family of sea slugs (>300 valid species), is a good – or bad – example. The first revision of the genera of this family was carried out by Rudman (1984, 1987). Next Gosliner and co-workers described additional species and revised several genera (Gosliner, 1996; Gosliner and Behrens, 1998, 2000; Johnson and Gosliner, 1998, 2001; Gosliner and Johnson, 1999; Valdés and Gosliner, 1999; Valdés *et al.*, 1999; Johnson and Valdés, 2001; Gosliner *et al.*, 2004; Alejandrino and Valdés, 2006). And most recently the accepted generic division was again split up and some old genus names reinstated

(Turner and Wilson, 2008; Johnson, 2010; Johnson and Gosliner, 2012). For each revision and/or phylogenetic study names have been changed, species synonymized and new species names have been introduced. Name changes make it difficult for database managers to follow the “fate” of specific taxa.

Conservation managers need stable species lists for setting priorities of protected areas (Giangrande, 2003; Mace, 2004; Khuroo *et al.*, 2007). Also pharmacologists, physiologists and biochemists need to be certain about species identification. Faulty identifications may be worse than incomplete lists (Bortolus, 2008), and name changes resulting from phylogenetic analyses may have widely different effects on conservation actions (Morrison *et al.*, 2009; Dayrat, 2011), though species are not actually “lost” when moved from one genus to another. Species richness may decrease if species are synonymized, but probably the combined populations then turn out to be more common and less threatened. For chemical and molecular studies it is necessary that voucher specimens are deposited in recognized museums and that publications contain information on how species were identified (Schander and Willassen, 2005; Pleijel *et al.*, 2008; Wägele *et al.*, 2011). For sea slugs voucher specimens should be accompanied by color pictures because colors disappear and body shape is altered by preservation (Jensen, 1999).

Specimen availability

Most divers and underwater photographers, being conscious about the environment and biodiversity conservation, “collect” only pictures of sea slugs. When taxonomists are not able to identify species from pictures and suspect that it may be an un-described species, they would like to obtain preserved specimens. This is where serious obstacles to the fruitful collaboration between local divers and foreign taxonomists may be encountered. Sea slugs are often habitat specific and thus apparently rare, i.e. only one or two specimens are observed at one time and place. In some cases it may be possible to obtain specimens by providing instructions for proper fixation and shipment to the local divers who can then collect the specimens when they see them again and ship them to the scientists. However, problems may arise if (1) the species has been observed only in a protected area where collection is prohibited, (2) there are national regulations prohibiting export of “biodiversity”, (3) shipping regulations may prohibit certain kinds or quantities of chemicals used for preserving

specimens (Renner *et al.*, 2012). As most sea slugs are small, shipping in itself is rarely a problem. Most of the liquid fixative can be drained prior to shipping and plenty of absorbent packing material supplied to keep the specimen moist.

It is of utmost importance that collectors, whether foreign or local, professional taxonomists or amateurs, obtain the necessary permits for collecting and exporting specimens for research. Collaboration with local research institutions and universities may facilitate this process. Specimens obtained without the appropriate permits may not be accepted by museums for deposition of type material, and papers may be refused for publication if material has been obtained illegally. Many sea slugs are too small to see in the field, and it may be necessary to collect their substrate, such as hydroids, bryozoans or algae for sorting under a microscope (Jensen, 1999; Mikkelsen and Cracraft, 2001). It may be difficult to state exactly what and how much will need to be collected to obtain enough specimens of a species that has only been photographed once or a few times, but if local scientists can explain this problem to conservation officers, it should be possible to overcome this problem. Applying for a permit in connection with a collaborative general marine biodiversity workshop may be easier than trying to apply for a permit to collect a few specific organisms, which then may not be found for the duration of the permit.

Funding for taxonomic research is scarce, and most taxonomists cannot pay large fees for permits as can medical companies doing bioprospecting work. When applying for a collecting permit for taxonomic research it should be stressed that no commercial interests, such as bioprospecting, are involved, that the species are not endangered or protected by international conventions, that type material will be deposited in the country of origin (or as required by national regulations), and that published descriptions will be made available to authorities and scientists in the country of origin. For a successful collaboration, applications for collecting and export permits might also have provisions for training of local students and scientists. Further recommendations can be found in a publication from the secretariat of the Convention on Biological Diversity (CBD, 2007). Unfortunately many developing countries have bad experiences with foreign scientists collaborating with the local scientists only during the field work and then taking all the profits and patents, and it may be very difficult and costly to obtain a collecting permit (Bouchet, 2006). The fact that there may be a long time-lag between collecting specimens and

publication may also leave the local collaborators frustrated (Evenhuis, 2007), but as explained above, a 10-year lag is not uncommon. Publication of separate, but peer-reviewed workshop proceedings two to three years after the workshop has been successful in the past (see review by Morton, 2003). Recent focus on Impact Factors and the like may have made this solution obsolete. On the other hand it is also necessary that the local students, divers, boat-operators, etc. do not use the information they obtain concerning rarity and value of new species to create a private business collecting and selling specimens to aquarium traders or pharmaceutical companies. Participating in basic biodiversity research carries a responsibility to utilize the information for the conservation of that biodiversity, at least to prevent the loss of biodiversity.

Taxonomic problems

Classification in the Opisthobranchia was originally based on the presence or absence of a shell and only two orders were recognized: Tectibranchia with a shell and Nudibranchia without a shell. However, it was soon realized that some “tectibranchs” were more closely related to some “nudibranchs” than to other “tectibranchs”; some sea hares had an internal shell, and the same was seen in some side-gilled slugs. In the sap-sucking Sacoglossa some species had an external shell, and in 1959 a living bivalved sacoglossan was discovered (Kawaguti and Baba, 1959). Thus the shell has been reduced and/or lost in several groups of opisthobranchs (Mikkelsen, 1998; Jensen, 1999; Wägele and Klussmann-Kolb, 2005), and parallel evolution is also seen in other organ systems, such as the concentration and de-torsion of the nervous system, or the development of cerata containing branches of the digestive gland (Gosliner and Ghiselin, 1984; Huber, 1993; Jensen, 1996). Nevertheless classification remained fairly stable, with the exception of a few groups, e.g. Pyramidellidae, that have repeatedly been included and excluded (Schmekel, 1985; Graham, 1988; Jensen, 2000).

In recent years the traditional classification of the Gastropoda has been seriously challenged by increased use of cladistic analysis based on morphological characters and on molecular data, and many new names for higher taxa have been introduced (Thollessen, 1999; Wollscheid-Lengeling *et al.*, 2001). Presently the Opisthobranchia is included in the subclass Heterobranchia, which also comprises the Pulmonata (most of the terrestrial and freshwater snails and slugs) and some

smaller snail families (Haszprunar, 1988; Grande *et al.*, 2004; Wägele *et al.*, 2008; Jörger *et al.*, 2010). Furthermore the opisthobranchs are presently not considered a monophyletic group, and “Opisthobranchia” should therefore be in quotation marks (Schrödl *et al.*, 2011). Molecular studies indicate relationship between the Sacoglossa and the Siphonariidae, but whether both groups should be included in a Panpulmonata group, or the Siphonariidae should be relocated to “opisthobranchs”, or both are basal within the Euthyneura is unclear (Dinapoli and Klussmann-Kolb, 2010; Dayrat *et al.*, 2011; Dinapoli *et al.*, 2011), and comparative anatomical studies show only superficial similarities (Jensen, 2011). The mostly interstitial Acochliidae have also been moved from their traditional inclusion in “Opisthobranchia” (Jörger *et al.*, 2010), and the recently described Aitengidae (Swennen and Buatip, 2009) has been included in the Acochliidae (Neusser *et al.*, 2011).

This reorganization of opisthobranch classification has caused a lot of confusion among divers, and also among conservation biologists who like their species lists to be complete, i.e., no name changes and no unidentified species. Many professional taxonomists have been so deeply involved in the testing of new phylogenetic hypotheses that describing new species has been given low priority. Fortunately some taxonomists, including amateurs and retirees, continue to discover and describe species, and habitats other than coral reefs have yielded some interesting results (Swennen, 2001, 2007, 2011; Swennen and Buatip, 2009; Brenzinger *et al.*, 2011; Neusser *et al.*, 2011).

The Indonesian connection

The first sea slug described from Indonesia is probably a sea hare collected by Rumphius in Ambon in the second half of the 17th century, and later described as *Dolabella rumphii* Blainville, 1819 (Engel, 1942), which is currently known as *D. auricularia* (Lightfoot, 1786). Later van Hasselt described several species of opisthobranchs from Java (van Hasselt, 1824; Bergh, 1887), and later still the Siboga Expedition collected opisthobranchs, which were described by Bergh (1905). More recently some of the nudibranchs collected during the Rumphius Biohistorical Expedition in 1990 have been described (Yonow, 2001, 2011), and a checklist of molluscs from Bunaken National Park has been published in collaboration between German and Indonesian scientists (Burghardt *et al.*, 2006). The latter

illustrates the problems outlined above very well. The list contains 49 identified opisthobranch species, 9 tentatively identified (cf.), and 31 only identified to genus or family, and the authors estimated that 26% of the 89 species were undescribed. Obviously the Indonesian sea slug fauna comprise a high proportion of un-described species, but with appropriate collaborations the number of described species should become at least as high as that of the Philippines (563 species), Papua New Guinea (646 species) and Guam (485 species) (Gosliner, 2000; Carlson and Hoff, 2003).

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